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IMPROVEMENT OF THE SEX-RATIO OF A PARASITE BY SELECTION

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It is a well known fact, noticed by many workers engaged in breeding hymenopterous parasites, that there is a tendency in many bisexual species for the sex-ratio to decrease as the breeding work proceeds over a series of generations. In a number of cases the sex-ratio decreases to an extent where only males are produced, and the stock dies out.

Usually when such decrease in sex-ratio occurs, experimental work is carried out with a view to improving it. The conditions of breeding are changed, on the asumption that the environment is not suitable for the parasite, or that there have been deficiencies in larval or adult feeding, adverse temperature effects on the immature or mature germ cells, etc.

In certain cases it has been claimed that improved sex-ratio has resulted from such treatment, but the problem still remains a serious one in view of the loss incurred in rearing an excess number of male parasites during biological control work. It was thought worth recording the improvement of sex-radio obtained by selective breeding in the course of the propagation for biological control purposes of *Aenoplex carpocapsae* (Cush.), a parasite of the codling moth, *Carpocapsa pomonella* (L.).

MATERIAL AND BREEDING METHOD.

During the summer of 1942, numbers of apple trees in the Niagara Peninsula, Ontario, were banded with burlap in order to collect hibernating codling moth larvae. In October, when the bands were removed and examined, 15,000 *Carpocapsa* larvae were obtained, together with 22 cocoons of *Aenoplex carpocapsae* (Cush.) of which *Carpocapsa* had been the host. These cocoons were kept at 75°F, and from them 5 males and 6 females emerged, the rest remaining in diapause. With these eleven adults, breeding work was commenced. Immediately on emergence, females were placed singly with two or three males, three or more days old, in a small cage (4½" x 4½" x 2½") with a wooden top and bottom, wooden sides into which was let a circle of muslin, a muslin back, and celluloid sliding front. Under these conditions, mating often occurred readily. If mating did not take place in these cages, the males and females were placed in a 1" x 4" vial, under which conditions further matings occurred. Females which for some reason could not be mated were discarded, only apparently mated females being used in the breeding work.

After mating, females were kept singly in 4½" x 4½" x 2½" cages constructed as above, in which was also placed:—a split raisin, a sugar lump, a cotton pad soaked in dilute honey water, and a small dish containing damp cotton wool.

Also with each female was placed a narrow (¼" x ½") strip of corrugated cardboard containing three or four hibernating larvae of *Carpocapsa*. These strips were changed each day, and the parasitised host larvae were removed and placed in ¼" diameter shell vials. The *Aenoplex* egg on the parasitised larva was placed in the vial with the host by means of a camel hair brush, and a tight cotton-wool plug was pushed down into the tube, so that the space surrounding the host larva was as small as possible. This was done to simulate, as closely as possible, the conditions prevailing with a larva paralysed within its cocoon. When the cotton-wool plug was left at the mouth of the vial, the parasite larva, on eclosion, tended to wander off the host larva and die, and also the host larvae tended to dry up more quickly than when the plug was forced

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down into the tube.

In many cases, host larvae were paralysed, but no egg was laid, and in others heavy superparasitism took place. Using paralysed but unparasitised larvae, the supernumerary eggs from the superparasitised hosts were transferred singly to fresh hosts, and when more eggs were obtained than there were hosts available, the eggs were placed on coddled larvae. These coddled larvae were obtained by removing hibernating *Carpocapsa* larvae from their cocoons, placing them in a wire-gauze sided tin, and immersing them for two minutes in water at 125°F. At this temperature and exposure time, nearly all the host larvae are killed, and remain intact without drying or decomposition longer than if a higher temperature or greater exposure are used in coddling.

LIFE HISTORY

Details of the life cycle of *Aenoplex*, have been given before by McClure (1933), who describes two types of life cycle in the male, a small larval type with a short "resting" period before pupation, and a larger type with longer "resting" period. These two types were not noticed in this breeding work. The egg stage lasts at 75°F. about two days, when a typical first stage ectoparasitic ichneumonid larva emerges; four stages are passed through in the next 5-7 days, when a cocoon is formed. After a further 3-4 days, the prepupa is formed, and the pupa two days later. The adult emerges about 6-8 days after pupa formation, making a total development time of 16-22 days. Mating can take place immediately on emergence of the females, after which a preoviposition period of one to several days follows. Unmated females also lay readily. Examination of a host cocoon is followed by stinging and subsequent oviposition. Usually a single egg is laid per host, but superparasitism is common.

TABLE I.

Biological characteristics of *Aenoplex carpocapsae* (Cush.)

	Reared at 75°F			Reared at 60°F-75°F Alternate		
	Min.	Max.	Average	Min.	Max.	Average
Length of life of females in days	13	84	35.1	19	57	37.3
Length of life of males in days			37.8			
Preoviposition period in days	1	17	5.0	2	17	6.7
Postoviposition period in days	0	18	5.4	1	16	7.4
No. of eggs per female	0	155	44.8* / 53.1	2	93	55.3
Length of egg stage in days	1	2	2			
Length of larval stage to spinning up	5	10	7.4			
Resting larval period in days	1	4	2.7			
Prepupa period in days	1	3	1.8			
Pupa period in days	5	9	6.9			
Total develop. time in days	16	22	18.8†			

*Including 8 females that laid no eggs.

†No significant difference between males and females.

In the present work conducted at 75°F. the following were some of the data obtained. In the micro-climate within a tightly stoppered vial, the humidity is presumably independent of slight variations in external humidity, and since the air in the vial is in contact with the host, it must have a high humidity.

As is seen from Table I, there is a very wide variation in the length of life of an adult, eggs laid per female, etc., and the means have no great significance.

SEX-RATIO.

Using the method of breeding outlined above, and using only females that had apparently mated successfully, large scale propagation was carried on in order to make shipments of the parasites. As this work proceeded, the sex-ratio became steadily less for four generations, as is shown in Table II. Under natural conditions, it would appear that the sex-ratio is about unity (here only 11 individuals emerged, giving 54.5% females). However by the fourth laboratory-bred generation this had dropped to 13.3% females, under which conditions

about three-quarters of the adults reared were wasted. In this fourth generation, however, there appeared two "families" (here "family" is used to denote the entire progeny of a single female) with 28.1% and 31.5% females respectively. Males from the former "family" were mated with two females from the latter, and the progeny from these two females were 88.0% and 62.1% females respectively. These and other females from the same groups increased the sex-ratio in the fifth generation to 36.3% females.

After this only matings were made between males and females selected from high sex-ratio "families", since the object of the work, naturally, was to produce material with a high sex-ratio. Brother-sister matings, and those between different "families", seemed to be equally successful in raising the general sex-ratio, and in the 6th and 7th generations, this was kept up to 26.6% and 39.3% females. Unfortunately, though a few back crosses were tried, no successful "families" were reared, owing to inability of females to lay, etc. The main result, however, was clear; that by selective matings, changing no other conditions, the decrease in the sex-ratio of laboratory bred *Aenoplex* was checked, and the ratio was then raised.

OTHER ATTEMPTS TO IMPROVE SEX-RATIO.

Other methods of improving the sex-ratio were also tried: 1) rearing the pupae at different temperatures, to determine if there were temperature effects on the immature gonads, which might induce male sterility, and thus affect the sex-ratio. 2) Keeping ovipositing females at a lower temperature at night, (as under natural conditions) since it was thought that continuous exposure to a temperature of 75°F. might prove lethal to the sperm in the female after copulation. That this latter was not true, was soon obvious, since with females kept at 75°F. there was no indication that the sex-ratio of the progeny tended to become less as the female became older, as would be expected if this effect

TABLE II.

Sex-Ratio of *Aenoplex carpocapsae* (Cush.) All individuals of each generation bred

Generation	No. of males	No. of females	Percentage of females
Parent (Field material)	5	6	54.5
F_1	65	22	25.3
F_2	123	35	22.2
F_3	153	35	18.6
F_4	215	33	13.3
F_5	100	57	36.3
F_6	138	50	26.6
F_7	37	24	39.3

was present. Since the adults were fed uniformly throughout the entire period, it was not felt that there could be anything varying in their diet that would account for the decrease in sex-ratio.

The results from keeping immature stages at different temperatures, were quite conclusive. Directly parasite larvae began to form their cocoons they were removed from 75°F and placed either at 85°F or 70°F, and left to pupate and emerge. Of 10 larvae placed at 85°F only a single individual, a female, emerged, and she laid no eggs. The rest developed normally to pupae or adults, but died in the cocoon without emerging. At 70° F development was slower than at 75°F but no great mortality occurred. Individuals reared at this temperature were apparently no different from those reared at 75°F, and the sex-ratio of their progeny was similar. The results of alternating the day and night temperatures (75°F-60°F) on the females is shown in Table I. It is obvious that with the numbers taken, there is no significant difference between these individuals, and those kept at 75°F. In sex-ratio of the progeny too, there was no significant difference between the two sets. Thus none of these attempts to increase the sex-ratio was successful, and conditions between the limits through which they were altered were not responsible for the drop in sex-ratio.

DISCUSSION

In the above breeding work, a declining sex-ratio has been increased by selective mating, using only for stock females from "families" with a high sex-ratio. Changing the temperature conditions under which the immature stages were reared, and under which the adults lived, had no effect on sex-ratio within the limits tried.

From this it would appear that the sex-ratio in this case is genetically determined, and that by continued selective mating considerable increase in sex-ratio over and above that obtained here might be possible. The problem is, however, not as simple as this. From Table I it is apparent that on bringing field material into the laboratory, the sex-ratio drops considerably in the first bred generation (54.5%-25.3% females). This substantial drop occurs when using a stock that has, presumably, fairly well-fixed potentialities for a sex-ratio of approximately unity. This could be caused by unsuccessful mating (even though the matings were apparently successful), but this factor would have acted steadily on the succeeding generations and is not in accordance with a steady decline in sex-ratio, and subsequent increase through selective mating. The cause of this initial drop is obscure.

It would appear that there are in the wild stock genetical factors, probably connected with male sterility which only become evident under conditions such as occur in the laboratory. Such male sterility would of course cause a predominance of males in the subsequent generation, and with the inbreeding that is bound to occur, this effect would be steadily accentuated.

However, when selective matings are made so that individuals are chosen from "families" in which this interaction of genetical and environmental factors favouring male sterility is not so pronounced (that is, from "families" showing a high sex-ratio), a strain can be bred in which the sex-ratio is increased, due to the breeding out of factors inducing male sterility. Other factors producing the same effect might be those associated with anatomical or physiological peculiarities of the female spermatheca, peculiarities of which could also affect the sex-ratio of the progeny. Also the success or otherwise of a mating might be determined by genetical factors. Though only apparently successfully mated females were used throughout the breeding work, it does not necessarily follow that the amount of sperm delivered at each pairing was adequate, or even that any was delivered at all. Hence apart from the quality of the sperm involved, there is also a question as to its quantity.

The exact nature of the cause of the declining sex-ratio was not investigated, since time did not permit of extensive experimental work, particularly with a species which requires about ten weeks from emergence to the emergence of the last of its progeny.

Under the conditions of breeding 30-40% of the eggs laid failed to produce mature larvae, and a further 5.2% of these did not complete their development. This suggests that a differential mortality between the sexes might be at least a contributory factor towards the low sex-ratio. However, the mortality in high sex-ratio "families" is the same as that in those with a low sex-ratio. Such mortality is however a disadvantage from the experimental point of view. Along with this, a number of the mature larvae (18.1% of the total, but again the same for high and low sex-ratio "families") do not emerge directly, but enter a state of diapause. Both of these factors decrease the suitability of *Aenoplex* as an experimental insect for such work.

The main result, however, is clear. Selective mating has in this case brought about a distinct increase in a sex-ratio that was declining under laboratory conditions and causing serious loss in mass breeding of parasite material.

LITERATURE CITED

McClure, H. E. 1933. Unusual variation in the life cycle of the male of *Aenoplex carpocapsae* Cush., codlin moth parasite. Ann. Ent. Soc. Amer., 26:345-347.

THE INFLUENCE OF AIR CURRENTS ON THE INSECTICIDAL ACTION OF DDT, BENZENE HEXACHLORIDE, HERCULES TOXICANT 3956, AND VELSICOL 1068.*

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In March, 1946, the writers reported in *Scientific Agriculture* (1) that benzene hexachloride showed pronounced fumigant action and that air currents as slow as 2 m.p.h. lowered its effectiveness against insects to a marked extent. The present paper deals with further experiments with benzene hexachloride and gives preliminary data on the fumigant action and effect of air currents on three other chlorinated hydrocarbons, viz., DDT, Hercules Toxicant 3956 (a chlorinated terpene) and Velsicol 1068 (a mixture of isomers with the empirical formul $C_{10}H_6Cl_8$).

Materials. DDT formulations used in the tests were (a) a commercial wettable spray powder containing 40% DDT, and (b) an emulsifiable solution of the following composition: DDT 20 grams, Atlox 1045 (emulsifier) 5 cc., and Velsicol AR60 to make 100 cc. Benzene hexachloride formulations used were (a) a commercial wettable spray powder, I.C.I. P530, containing 6% gamma isomer, and (b) refined benzene hexachloride containing 30% gama isomer, 20 grams, Atlox 1045 5 cc., and Velsicol AR60 to make 100 cc. The formulation of Velsicol 1068 employed was: Technical 1068 60 cc., Atlox 1045 5 cc., and Velsicol AR60 to make 100 cc. Hercules Toxicant 3956 was used (a) as a commercial wettable spray powder containing 25% 3956, and (b) as a commercial emulsifiable solution of 50% 3956.

In the composition of sprays, the amounts of materials refer in all cases to pounds of active ingredient per 100 *gallons (Imp.) of spray*, followed by the name and number of pounds of the formulation, or in the case of liquids the dilution in parts by volume, e.g., gamma benzene hexachloride 0.15 lb. (P530 2.5 lb.) and 3956 1 lb. (50% 3956 solution 1-1000).

Test Insects. The following species were used in the tests: diamondback moth, *Plutella maculipennis* (Curt.), larvae in last two instars; codling moth, *Carpocapsa pomonella* (L.), newly hatched larvae; large milkweed bug, *Oncopeltus fasciatus* (Dall.), adults; green chrysanthemum aphid, *Rhopalosiphum rufomaculatum* Wilson, apterous females; pear psylla, *Psylla pyricola* Foerst., second to fifth instar nymphs.

Methods. Sprays were applied in all cases with a power-driven DeVilbiss paint gun, hand-directed in some tests, and mounted on a rigid stand in others. The air current experiments were conducted in the greenhouse around circular tables below an office fan, the breeze being directed downward onto the centre of the table so that it spread outwards equally in all directions. Lantern globes placed on their sides around the circumference of the table so that the current was directed into their screened ends were used for tests with diamondback moth larvae (Fig. 1). For the tests with green chrysanthemum aphids, pots containing infested plants were placed on a stand below the edge of the table and all the leaves trimmed off except for the top 4 inches which extended above the table in the breeze (Fig. 2). The soil in the pot was covered with a plaster of hydrated lime and water so that dropped aphids could easily be counted. To prevent escape of the aphids a collar of gummed paper, smeared with a narrow band of tanglefoot, was fastened around the top of the pot as shown in Fig. 3. The pot was set in a saucer and water provided from below as needed.

Air currents of different velocities were obtained by varying the distance of the fan from the plants or cages, and by the use of screens of wire or cloth. Air velocity determinations were made with a sensitive anemometer at

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PLATE VI

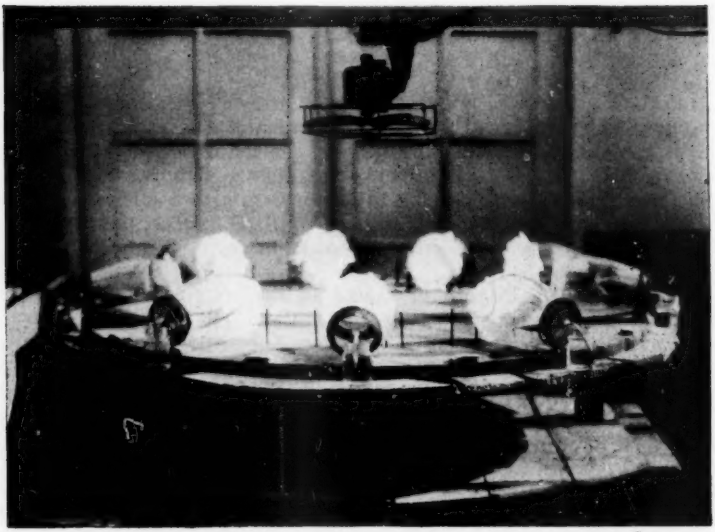

Fig. 1. Lantern globes used for insecticide tests with diamondback moth larvae. Stem of cabbage leaf extends through hole in 32-mesh screen into water in jar.

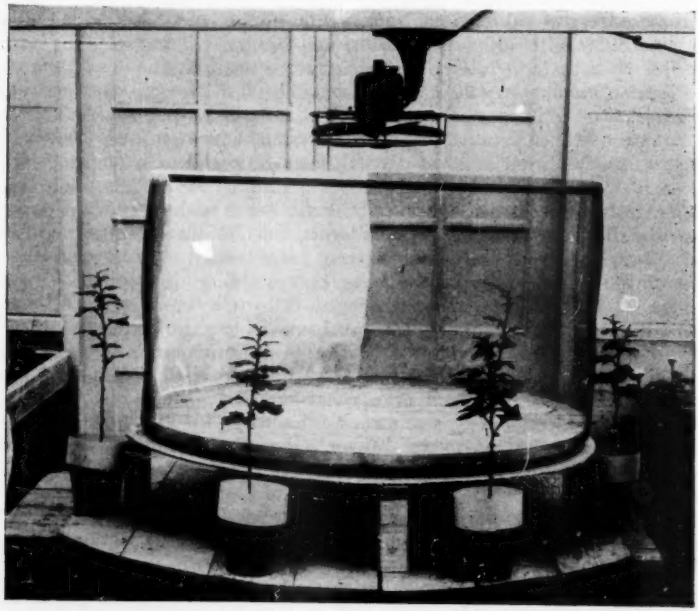

Fig. 2. Air current set-up for insecticide tests with green chrysanthemum aphid. Periphery of table is divided into three sectors, one open and two shielded with wire screen or cloth to provide lower air velocities.

the centre of the cage or test area of the plant, As the electric current varied somewhat throughout the day there was a corresponding variation in fan speeds which could not be accurately checked.

FUMIGANT ACTION

Fumigant action was checked in a preliminary way by placing relatively large amounts of insecticide in screened petri dishes in covered battery jars along with adult milkweed bugs. The fumigant action of DDT was nil, of 3956 slight, and of benezene hexachloride and 1068 very pronounced, as indicated in Table 1, which gives a summary of the results from several tests in which the amounts used varied from 5 to 10 grams of either technical DDT, technical 1068, 25% 3956 powder, or 6% gamma benzene hexachoride (P530). It is assumed that these were in excess of the amounts needed to saturate the space with fumes.

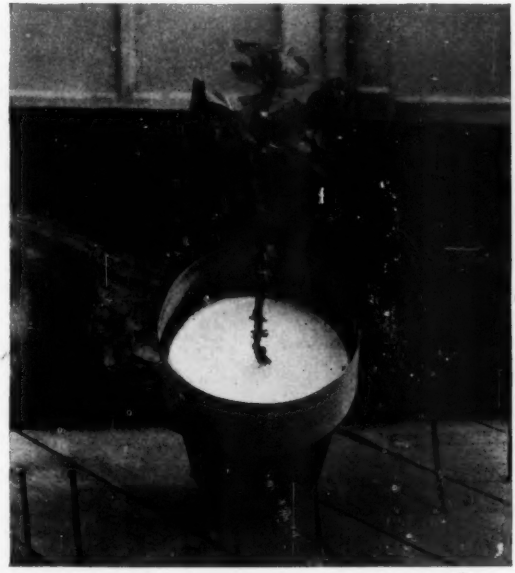

Fig. 3. Chrysanthemum plant used for insecticide tests against aphids.

Table 1. *Fumigant action of DDT, Benzene Hexachloride, Hercules* 3956 *and Velsicol* 1068 *Against Adult Milkweed Bugs in Battery Jars.*

Days exposed	Percentage mortality — cumulative				
	DDT	Benzene hexachloride	3956	1068	Check
1	0	26.6	6.6	66.6	0
2	0	80.0	6.6	100.0	0
3	0	80.0	6.6		6.6
4	13.3	100.0	40.0		6.6

EFFECT OF AIR CURRENTS

Experiment No. 1. In tests with diamondback moth larvae, pieces of cabbage leaf bearing the dry deposit from a spray of gamma benzene hexachloride 0.24 lbs. (P530 4 lb.) per 100 gal. were placed with the larvae in pint glass jars covered with glass, factory cotton or cheesecloth, or in lantern globes resting on their sides with one end covered with cheesecloth and the other with 32-mesh wire screen. In all cases mortality was complete within 5 days, and only a trace of feeding was present. However, when an air current at 3 m.p.h. was

directed at one end of the lantern globes (Fig. 1), mortality was only 57.5% within the same period, and 5% of the foliage was consumed.

Many experiments with DDT against diamondback moth larvae in open and closed containers of various types have shown that ventilation has no effect on rate or degree of mortality.

Experiment 2. *Green Chrysanthemum Aphid.* Gamma benzene hexachloride 0.075 lb. (P530 1.25 lb.) was applied to infested chrysanthemums which were then placed in air currents about the circular stand previously described. The results in Table 2 show marked loss of toxicity with increase in air velocity.

Table 2. *Effect of Air Currents on Toxicity of Benzene Hexachloride to Green Chrysanthemum Aphid.*

Air velocity m. p. h.	No. living	No. dead	Percentage mortality
4.5	312	1065	77.4
2.7	193	970	83.5
1.5	72	1604	95.7
0	29	1429	97.9

Experiment 3. This test was similar to Experiment 2, but benezene hexachloride was applied at three rates. It will be noted in Table 3 that at the lowest rate the difference due to air currents was very marked, mortality varying from 29.3% in air moving at 4.5 m.p.h. to 86.5% in still air. The kill by 0.037 lb. gamma benzene hexachloride in still air was higher than that given by four times that amount of insecticide in air moving at 2.7 m.p.h.

Table 3. *Effect of Air Currents on Toxicity of Benzene Hexachloride to Green Chrysanthemum Aphid.*

Materials: lb. per 100 gal.

Formulation P530	Active ingredient (gamma benzene hexachloride)	Air speed m.p.h	No. living	No. dead	Percentage mortality
0.62	0.037	4.5	855	354	29.3
0.62	0.037	2.7	550	641	53.8
0.62	0.037	1.5	419	1209	74.3
0.62	0.037	0	216	1363	86.5
1.25	0.075	4.5	318	714	68.5
1.25	0.075	2.7	354	979	73.5
1.25	0.075	1.5	107	1539	93.5
1.25	0.075	0	24	1278	98.5
2.5	0.15	4.5	144	508	79.1
2.5	0.15	2.7	237	637	72.8
2.5	0.15	1.5	26	1137	97.7
2.5	0.15	0	2	1367	99.9

Mortality in checks approx. 7%.

Experiment 4. Seven groups of chrysanthemums infested with green chrysanthemum aphids were sprayed with gamma benzene hexachloride 0.037 lb. (P530 0.62 lb.). One group was left in still air and the other 6 groups placed in an air current of 4.5 m.p.h.; at varying intervals thereafter single groups were returned to still air. Table 4 shows that aphid mortality steadily decreased as the length of the exposure to the air current increased, thus indicating that benzene hexachloride was still exerting some fumigant action 48 hours after being applied.

Table 4 *Effect of Varying Length of Exposure to Air Currents on Toxicity of Benzene Hexachloride to Green Chrysanthemum Aphid.*

Hours in air current of 4.5 m.p.h.	Hours in still air	No. living	No. dead	Percentage mortality
0	48	458	1060	69.9
0.5	47.5	598	1033	63.4
1	47	867	916	51.5
4	44	1220	978	44.6
12	36	1114	425	27.6
24	24	1275	248	16.3
48	0	1383	199	12.6
Unsprayed checks		928	82	8.1

Experiment 5. Air currents are shown in Table 5 to have little or no effect on the toxicity of DDT to the green chrysanthemum aphid, but to have a marked effect on the toxicity of Velsicol 1068.

Table 5. *Influence of Air Currents on Toxicity of DDT and Velsicol* 1068 *to Green Chrysanthemum Aphid.*

Materials Dilution by parts	Active ingredient lb./100 gal.	Air speed m.p.h	No. living	No. dead	Percentage mortality
50% 1068 soln. 1-4800	0.125	3.7	750	43	5.4
" " " 1-4800	0.125	2.7	691	99	12.5
" " " 1-4800	0.125	0.9	1104	247	18.3
" " " 1-4800	0.125	0	769	222	22.4
50% 1068 soln. 1-1200	0.5	3.7	400	215	35.0
" " " 1-1200	0.5	2.7	607	408	40.3
" " " 1-1200	0.5	0.9	90	813	90.0
" " " 1-1200	0.5	0	88	640	87.9
20% DDT soln. 1-800	0.25	3.7	21	507	95.8
" " " 1-800	0.25	2.7	9	605	98.5
" " " 1-800	0.25	0.9	7	773	99.1
" " " 1-800	0.25	0	6	720	99.2
Unsprayed check		—	816	89	9.0

Experiment 6. The kill of green chrysanthemum aphids by both wettable spray powders and emulsions of Hercules 3956 was influenced by air currents in this single test, but further experiments are necessary to confirm this effect. It will be noted in Table 6 that again wind had no significant influence on DDT.

Table 6. *Effect of Air Currents on Toxicity of Hercules* 3956 *and DDT to Green Chrysanthemum Aphid.*

Materials; lb. per 100 gal. or dilution by parts	Active ingredient lb./100 gal.	Airspeed m.p.h	No. living	No. dead	Percentage mortality
40% DDT powder 1.25	0.5	3	651	330	33.6
" " " 1.25	0.5	0	714	451	39.2
25% 3956 powder 2.0	0.5	3	349	443	56.0
" " " 2.0	0.5	0	302	690	69.5
50% 3956 solution 1-2000	0.25	3.2	93	169	64.5
" " " 1-2000	0.25	0	14	790	98.3

Experiment 7. *Pear Psylla.* Second to fifth instar pear psylla nymphs on potted pear seedlings were sprayed and immediately exposed to air currents as in the case of aphids, and mortality records taken 3 days later. The results given in Table 7 show that air currents lowered mortality appreciably.

Table 7. *Effect of Air Currents on Toxicity of Benzene Hexachloride to Pear Psylla Nymphs.*

Materials ; lb. per 100 gal. Formulation P530	Active ingredient (gamma benzene hexachloride)	Air Speed m.p.h	No. living	No. dead	Percentage mortality
0.5	0.03	3.2	68	295	81.2
0.5	0.03	2.3	61	197	76.3
0.5	0.03	1.0	23	314	93.1
0.5	0.03	0	5	585	99.2
1.0	0.06	3.2	58	365	86.3
1.0	0.06	2.3	24	553	95.8
1.0	0.06	1.0	13	506	97.5
2.0	0.12	3.2	8	193	96.0
2.0	0.12	2.3	27	348	92.8
2.0	0.12	0	0	629	100.0
Check			396	22	5.3

Experiment 8. *Codling Moth.* In the authors' previous paper cited above, gamma benzene hexachloride was claimed to be more toxic than DDT

to newly hatched codling moth larvae, on the basis of a few preliminary tests carried on in 1945. In the spring of 1946 work was continued on a large scale to compare the toxicity of different formulations of benzene hexachloride. It was soon found, however, that this could not be done because of the very great variation of efficiency among replicates of the different formulations. In all these tests the fan providing air circulation in the incubator containing the fruit was run at a speed just sufficient to prevent stratification. Following the lead given by some of the greenhouse experiments with other insects, the speed of the fan was increased to give an air current perceptible in the heating compartment but which could scarcely be detected in the body of the incubator. Following this change, the variation among replicates was greatly reduced but the control given by benzene hexachloride dropped considerably below that afforded by DDT.

An example of the results obtained at the higher fan speed is given in Table 8; in these tests the fruits sprayed with each material were divided into 3 lots, one being tested immediately and the other two being held for 3 and 6 days respectively at a temperature of about 50°F. in a room with fan-produced air circulation. Other formulations of benzene hexachloride tested on a smaller scale gave as poor or poorer results.

The high efficiency shown by benzene hexachloride in the preliminary tests reported in the author's earlier paper was undoubtedly due to fumigant action, which was greatly reduced by a slight increase in air movement. The volatility of this compound which enabled it to act as a fumigant also led to graduaf loss of toxicity of the residue against codling moth larvae.

Table 8. *Relative Toxicity of DDT and Gamma benzene Hexachloride to Newly Hatched Codling Moth Larvae. Averages of 4 Replicates of 9 Fruits Each.*

Materials; lb. per 100 gal.		Age of spray deposit		
Formulation	Active ingredient	days	Total larvae	Percentage efficiency
40% DDT spray powder	DDT			
0.75	0.3	1	344	81.4
0.75	0.3	3	311	76.0
0.75	0.3	6	335	78.4
P530	Gamma benzene hexachloride			
5.0	0.3	1	338	50.0
5.0	0.3	3	314	42.3
5.0	0.3	6,	330	27.8

DISCUSSION

The data presented in this paper show the importance of air currents in influencing the effectiveness of insecticides which have fumigant action and suggest that this may be one reason why results obtained from insecticide tests in still air in the laboratory and greenhouse are often so much better than in the field.

SUMMARY

Exposure to air currents greatly reduced the effectiveness of those insecticides having pronounced fumigant action, namely benzene hexachloride and Velsicol 1068; caused some reduction in effectiveness of Hercules Toxicant 3956 which has less fumigant effect, and had no influence on the toxicity of DDT which is without fumigant action.

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1. Dustan, G. G., T. Armstrong and W. L. Putman, 1946. Preliminary experiments with benzene hexachloride (666) as an insecticide. Sci. Agr. 26 (3):106-121.

A REVISION OF THE GENUS *ARIGORYTES* (HYMENOPTERA: SPHECIDAE: GORYTINI)

BY V. S. L. PATE
Ithaca, New York

Rohwer established the genus *Argorytes* in 1912 for the reception of Fox's curious, stocky, little southern Californian species *Gorytes Coquillettii*. In the course of the ensuing thirty-five years, no subsequent investigator has recognized or admitted the validity of Rohwer's distinctive genus. In all probability, however, this is due largely to the relative rarity of the component species. In the past decade I have seen or assembled a number of specimens of this interesting genus and present below a revision of *Arigorytes*.

Arigorytes Rohwer

Gorytes Fox, Proc. Acad. Nat. Sci. Philadelphia, 1895, pp. 531, 532, (1895); [in part].
Hoplisoides Ashmead, Canad. Entom., XXXI, p. 328 (1899); [in part].—Baker, Invertebrata Pacifica, I, p 165, (1907); [in part].
Harpactus (?) Ashmead, Canad. Entom., XXXI, p. 329, (1899); [in part].
Gorytes (*Hoplisoides*) Bradley, Trans. Amer. Ent. Soc., XLVI, p. 118, (1920); [in part]. Maidl & Klima, Hymen, Catal., VIII, (1), pp. 89, 91, (1939); [in part].
Gorytes (*Arigorytes*) Maidl & Klima, Hymen, Catal. VIII. (1;, p. 66, (1939).
Arigorytes Rohwer, Proc. U. S. Nat. Mus., XLI, p. 469, (1912).—Rohwer, Proc. U. S. Nat. Mus., LXI, p. 412, (1921).—Pate, Mem. Amer. Ent. Soc., no. 9, p. 10, (1937).

GENOTYPE: *Gorytes Coquillettii* Fox, 1895 [=*Arigorytes Coquillettii* (Rohwer)]. (Monabasic and by original designation.)

The superficial habitus of *Arigorytes* is rather similar to that of *Dienoplus* to which it is closely related. From that genus, however, *Arigorytes* may be distinguished by the convergent inner eye orbits of both sexes, the rather highly placed antennal sockets, the short, subclavate antennae and the venation of the hind wing. In addition, the females have a pecten on the fore tarsi composed of very long, spatulate, flexible bristles, while the males have conspicuous brushes on the posterior portions on the third, fourth, and fifth abdominal sternites, and the seventh sternite is linguiform and completely obtect. Finally, the clypeus of *Arigorytes* is transversely subhexagonal whereas that of *Dienoplus* is transversely subrectangular.

Generic Diagnosis. Small, robust, finely to subtilely punctate forms. Head transversely oval in dorsal aspect, subcircular in anterior aspect. Eyes large, glabrous, facets uniform in size; reaching to bases of mandibles; inner orbits convergent toward clypeus in both sexes. Front broad; antennae short, subclavate, situated above dorsal margin of clypeus toward centre of face, the sockets about equidistant from each other and from nearest lower inner orbit; distinct subantennal sutures present; scape short, thick, subobconical; flagellum weakly clavate, simple in females, but in males with eighth and ninth segments more or less emarginate beneath. Ocelli simple, normal, situated in a curved line; the postocellar and ocellocular lines subequal. Occipital carina distinct but not a complete circle in extent nor attaining hypostomal carinule bordering the oral fossa. Clypeus transversely subhexagonal, twice as broad as long, transversely inflated medially, and with an apical flange. Maxillary palpi six-segmented, labial palpi four-segmented. Mandibles with apices acute; inner margins with a well developed preapical tooth; lower margins simple, entire.

Thorax robust. Pronotum very short, transversely sublinear, sharply perpendicular anteriorly, rounded and ecarinate above, situated on same level as mesonotum; the tubercles tumid. Propleura without a pronotal hamus. Mesonotal laminae squarely truncate, the obliquely declivous face strongly concave discally. Axillae, scutellum, and postscutellum simple. Mesopleura with episternal suture complete, running obliquely downward from below tegulae and joining the well developed omaulus; episternauli present and well developed, oblique; sternauli distinct, joining omauli anteriorly. Metapleura broad, tapering ventrally. Mesosternum rounded, ecarinate anteriorly. Propodeum on

dorsal face with a well developed trigonal enclosure which is delimited by a strongly foveolate groove; stigmatal grooves completely absent; lateral carinae absent.

Legs short, stout. Tibial calcaria 1-2-2 in both sexes. Females with a pecten of long flexible, flattened, more or less spatulate bristles on fore tarsi. Males with hind tarsi sometimes swollen or inflated. Last tarsal segment large, the pulvillus large and distinct.

Fore wings generally clear, without fuscous clouds or markings; marginal cell elongate lanceolate; radius arising from apex of stigma; three submarginal cells, the second sessile, trapeziform, and receiving both recurrent veins; the third large rhomboidal; basal vein arising distinctly before transverse median vein. Hind wings with cubitus and transverse median veins more or less interstitial; anal lobe large, about one-third the length of submedian cell.

Abdomen fusiform, sessile, without appreciable constriction between any segments. Males with seven tergites clearly visible, the last with a more or less distinct, narrow, elongate, subrectangular to subtrigonal pygidial area; third, fourth and fifth sternites with conspicuous apical brushes of golden hair; sixth sternite forming a pseudohypopygium, simple, the apical portion subtrigonal; seventh sternite linguiform, completely obtect; eighth sternite obtect, more or less membranous. Females with a broad trigonal pygidial area.

Ethology. Nothing is known about the biology of the species of *Arigorytes*. The females, however, have a pecten on the fore tarsi composed of long flexible, subspatulate, flattened bristles. This indicates the species are fossorial forms which, like many other Gorytines, nest in the ground and provision their burrows with other insects.

Distribution. The genus *Arigorytes* is a precinctive Nearctic entity, confined to western North America, and apparently restricted to the area west of the continental divide. The known species are all apparently marked xerophiles, and are distributed, in the main, about the fringes of the arid Great Basin area of the western United States. This suggests that *Arigorytes* may be a Tertiary Great Basin relict group.

Rohwer knew only the genotypic species — *Coquillettii* —, but now there are several additional forms known which are referable to *Arigorytes*. The subjoined table will serve to differentiate these species.

Key to the Species

1. Antennae thirteen-segmented; seven abdominal tergites clearly visible; (males) 2
   Antennae twelve-segmented; only six abdominal tergites clearly visible; (females) 4
2. Propodeum with lateral faces horizontally costulate; clypeus black with apical flange deeply notched medio-apically, the disc flatly tumid and distinctly, closely punctate; ventral abdominal brushes weak; [Columbian Plateaux; Idaho to Washington] ..... *smohalla* new species
   Propodeum with lateral faces merely punctate; clypeus yellow, with apical flange entire or merely gently retuse medially, the disc strongly transversely tumid and indistinctly punctate; ventral abdominal brushes strong 3
3. Propodeum with trigonal dorsal enclosure merely punctate or very finely, indistinctly striate; mesopleura immaculate; abdomen with first segment, second sternite and sides of second and third tergites, ferruginous; smaller forms, about 6 mm. long; [southern California] ..... *Coquillettii* (Fox)
   Propodeum with trigonal dorsal enclosure strongly, coarsely, obliquely canaliculate-carinulate; mesopleura with a spot behind tegulae; abdomen not ferruginous at base; larger forms, about 9 mm. long; [California and Nevada] ..... *insolitus* (Fox)

4. Pygidial area longitudinally straitorugulose 5
Pygidial area merely finely punctuate 6

5. Fore wings clear hyaline throughout; stigma brunneous, concolorous with veins. Clypeus with apical flange deeply notched medially. Propodeum with trigonal enclosure of dorsal face radiately rugulose and margined by a broad, foveolate furrow; posteriorly face densely pubescent laterally, bisected below by a marginate furrow; lateral faces costulate. Thorax, propodeum, abdomen and legs black, maculated with eburneous. Finely punctate forms. [Columbian Plateaux: Idaho to Washington] ..... *smohalla* new species

Fore wings with marginal and second submarginal cells with a fuscous cloud; veins brunneous, the stigma abruptly eburneous-testaceous. Clypeus with apical flange entire, not notched medially. Propodeum with trigonal dorsal enclosure radiately grooved on basal two-thirds, the posterior and lateral faces merely punctate. Metapleura, propodeum (except trigonal dorsal enclosure), first two abdominal segments, and all legs, ferruginous. Head, thorax and abdomen with scattered coarse punctures. [Sonoran Desert, southern Arizona] ..... *anaëtis* new species

6. Propodeum with trigonal dorsal enclosure radiately grooved and bisected by an inconspicuous, immarginate groove; first two abdominal segments ferruginous; mesopleura immaculate. [southern California] ..... *Coquillettii* (Fox)

Propodeum with trigonal dorsal enclosure radiately rugulose, bisected by a narrow marginate groove; first two abdominal segments black; mesopleura with a spot behind pronotal tubercles. [Nevada to California] ..... *insolitus* (Fox)

Arigorytes Coquillettii (Fox)

Gorytes Coquillettii Fox, Proc. Acad. Nat. Sci. Philadelphia, 1895, p. 531, (1895) [♀; Los Angeles, California].
Hoplisoides Coquiletti Ashmead, Canad. Entom., XXXI, p. 328, (1899).
Arigorytes coquillettei Rohwer, Proc. U. S. Nat. Mus., XLI, p. 469 (1912); [♀].
Gorytes (Hoplisoides) insolitus Bradley, Trans. Amer. Ent. Soc. XLVI, p. 118, (1920); [♂, Claremont, California]. (Not of Fox, 1895).
Arigorytes Coquillettii Pate, Mem. Amer. Ent. Soc. no. 9, p. 10, (1937).
Gorytes (Arigorytes) coquillettii Maidl & Klima, Hymen. Catal., VIII, (1), p. 66, (1939); [♀].

Type ♀; Los Angeles, California. (D. W. Coquillett.) [United States National Museum, Type no. 1894.]

This brightly ornamented little species is distinguished from the other members of the genus by the red basal segments of the abdomen, the subtile puncturation and delicate sculpture, and the inflated hind tarsi of the males.

Specimens examined: 2; 1 female, 1 male, as follows:

CALIFORNIA: Los Angeles; (D. W. Coquillett): ♀; [*Type*, U. S. N. M.]. Claremont; (C. F. Baker): ♂.

Distribution. At present, *Coquillettii* is known only from the piedmont of the Transverse Ranges region of southern California.

Arigorytes insolitus (Fox)

Gorytes insolitus Fox, Proc. Acad. Nat. Sci. Philadelphia, 1895, p. 532, (1895); [1 ♂; Southern California. Nevada.].
Harpactus (?) insolitus Ashmead, Canad. Entom., XXXI., p. 329, (1899).
Gorytes (Hoplisoides) insolitus Maidl & Klima, Hymen. Catal., VIII, (1), p. 91 (1939); [♂].

Type. ♂; Southern California. (No other data.). [Academy of Natural Sciences of Philadelphia, Type no. 4803.]

The present species is considerably larger than *Coquillettii*, and, moreover, *insolitus* lacks any ferruginous on the abdomen. The mesopleura, on the other hand, are spotted, the body is more distinctly punctate, and the sculpture, particularly that of the propodeum, is much coarser than in *Coquillettii*.

Specimens examined: 5; 2 males, three females, as follows:

CALIFORNIA: Southern California; (no other data): ♂; [*type*, A. N. S. P.]. Siskiyou County; May 28, 1911; (F. W. Nunnemacher): ♀; [U. S. N. M.]. Silver Lake, El Dorado County; August 11, 1936; ♀. Bates, Madera County; April 4, 1917: ♀; [A. M. N. H.].

NEVADA: Nevada (no other data: ♂; [paratype, A. N. S. P.].

Distribution. The present species ranges from western Nevada, across the Sierra Nevada into the central California Trough and thence northward into the Klamath Mountains section of northern California. The southernmost limits of its distribution are still unknown: the type merely bears the label "S[outhern] Calif[ornia]".

Arigorytes smohalla* n. sp.

The coarsely sculptured propodeum, the lateral faces of which are strongly costulate, the sharply notched medio-apical clypeal flange, and the rugulose pygidial area of the female, differentiate *smohalla* from all other species of *Arigorytes*.

Type. ♂; Boise, Ada County, Idaho, Elevation, 2700 feet, June 13, 1915. (A. K. Fisher.) [United States National Museum, Cat. no. 26659.]

Male. Length 7 mm. Black; the following stramineous: antennal flagellum beneath, a small spot at tip of scape; pronotum dorsally and tubercles; tegulae with a small discal spot; scutellum with a large, transverse, oval spot posteriorly; first five abdominal tergites with apical fasciae and disc of sixth tergite; fore and middle femora with an elongate spot apically beneath; fore and middle tibiae with a small spot at base; middle tibiae with an elongate spot on outer face at apex; hind tibiae with a stripe on outer faces; middle metatarsi with a small spot on anterior face. Fulvous: fore and middle tarsi. Brunneous: hind tarsi; tegulae and axillary sclerites. Wings clear hyaline; stigma and veins brunneous.

Head with clypeus (except medio-apically) and lower front with appressed, silvery sericeous pile; upper front, vertex and temples more thinly clad with decumbent, puberulent, silvery hair; in addition, upper front and vertex with a moderate vestiture of long, erect, silvery hair. Eyes with inner orbits straight, moderately convergent toward clypeus. Front, vertex, and upper half of clypeus, with fine close puncturation upon which is superposed a series of scattered, coarser, setigerous punctures. Vertex with postocellar and ocellocular line subequal. Antennae situated one-third of the length of the scape above the dorsal margin of clypeus; subantennal suture moderately distinct; interantennal and antennocular lines subequal; scapes thick, obconical, about three-eighths (0.36) the vertical eye length; pedicel suborcate; flagellum gently clavate apically, the tenth weakly, and the eighth and ninth segments strongly, emarginate beneath, the last article weakly, arcuately terete; relative lengths: scape 18; pedicel 5; flagellar article one 8, two 5, three 5, four 5, five 5, six 5, seven 6, eight 9, nine 8, ten 9, eleven 12. Clypeus transversely subhexagonal, the median length two-fifths the vertical eye length, and two and a quarter times as wide as long medially; transversely tumid; the upper half finely punctate; medio-distally glabrous, nitidous, without fine punctures but with a few scattered coarse punctures; apical flange deeply notched medially.

Thorax with a moderate vestiture of decumbent puberulent hair, aeneous dorsally, silvery on pleura and venter; with fine, rather close puncturation throughout. Mesonotum with notauli indicated on anterior fourth. Scutellum flat; anterior margin strongly, coarsely foveolate; postscutellum transversely tumid. Mesopleura with episternal suture, episternauli, omauli, and sternauli all well developed; puncturation fine, close, causing surface to be subopaque. Metapleura finely punctate and with fine, horizontal rugulae. Propodeum with a vestiture of erect to decumbent short silvery hair; dorsal face with trig-

*Smohalla sive Shmoqŭla — the Sokulk Nez Percés Indian prophet.

onal enclosure very large, delimited by a coarsely foveolate groove, and rather coarsely and somewhat irregularly carinulate within, bisected by a narrow, linear, marginate groove, lateral areas and posterior face, which is bisected by a polite marginate groove, granulate and rather coarsely areolate; lateral faces punctate and with rather coarse parallel horizontal carinules.

Legs simple. Middle and hind tibiae very weakly spinose on outer faces. Hind metatarsi not appreciably thickened or inflated. Longer hind tibial calcar one-half the length of hind metatarsi.

Hind wings with cubitus arising slightly before the transverse median vein.

Abdomen with a thin clothing of decumbent puberulent silvery hair; ventral brushes on third, fourth and fifth sternites weak, very light golden. No appreciable constriction between the segments. Tergites and sternites with a rather fine, close, uniform puncturation throughout. Last tergite with an elongate subtrigonal pygidial area, the apex of which is truncate, the disc somewhat more coarsely punctate than preceding tergites. Sixth sternite polite, with a few scattered, setigerous punctures, the apex bluntly trigonal; seventh sternite linguiform, completely obtect.

Allotype. ♀; Spokane, Washington. Elevation, 1900 feet. June 25, 1900. (J. M. Aldrich.) [United States National Museum.]

Female. Length 8 mm. Agrees with the male (type) except in the following details:

Livery essentially same but fascia of first abdominal tergite interrupted medially.

Head with puncturation; vestiture and relative measurements the same. Antennal flagellum broken, missing beyond first flagellar article. Clypeal flange strongly notched.

Alitrunk similar but propodeum somewhat more coarsely sculptured.

Legs with middle and hind tibiae and hind metatarsi rather strongly spinose.

Abdomen with pygidial area longitudinally striatorugulose. Sternites with microscopically fine cancellate sculpture upon which is superposed a few scattered, fine punctures.

Distribution. This distinctive species, which is known from only the unique pair described above, ranges throughout the eastern fringes of the Columbian Plateaux, from the Snake River Plain in southern Idaho northward to the Walla Walla Plateau in eastern Washington.

Arigorytes anaëtis* n. sp.

The red propodeum, legs, and basal abdominal segments, together with the pictured wings and eburneous stigma, and coarsely rugulose pygidial area of the female, readily distinguish *anaëtis* from all other species of *Arigorytes*.

Type. ♀; In cemetery about one mile north of Nogales, Santa Cruz County, Arizona. Elevation, about 3860 feet. August 9, 1946. (Howard E. Evans; at flowers of *Tamarix gallica* L.) [Academy of Natural Sciences of Philadelphia, Type no. 10602.]

Female. Length 9 mm. Black; the following dark ferruginous: clypeal flange; scape with a longitudinal stripe laterally; pedicel (infuscated somewhat above); flagellum; pronotal tubercles; tegulae and axillary sclerites; mesonotal laminae; mesopleura with a small indistinct spot just behind pronotal tubercles and a large indefinite one ventrally; upper half of metapleura; propodeum entirely save for dorsal trigonal enclosure which is black; all legs completely; first two abdominal segments. Mandibles badeous, apices red. Stramineous: pronotum dorsally; posterior half of scutellum; first four abdominal tergites with broad apical fasciae, widened laterally, that of first narrowly interrupted medially. Wings clear hyaline, with a heavy fuscous cloud filling marginal

*Gr. *anaëtis:—an* + *aëtos.*

and second submarginal cells of fore wing; veins brunneous, the stigma eburneous.

Head subfulgid; front, vertex, and upper half of clypeus clothed with fine, appressed, silvery sericeous pile which is somewhat aureous above; temples with fine, appressed, silvery puberulent hair. Front with very fine, close, setigerous puncturation upon which is superposed rather coarse, scattered punctures; bisected by an impression running down from median ocellus, and with a broad, shallow furrow running up from each antennal socket. Vertex punctured like front; ocelli in a very low triangle, the ocellocular line three-fourth the postocellar distance; each ocellus slightly elevated in a depression. Temples with a few scattered, moderate punctures. Antennae situated about one-fifth the length of scape above dorsal margin of clypeus; interantennal line one-half the antennocular distance; scapes thick, obconical, one-half the vertical eye length; pedicle subglobose; flagellum gently clavate apically; relative lengths: scape 27; pedicel 6; flagellar article one 12, two 8, three 7, nine 8, ten 11. Clypeus subhexagonal; median length one-half the vertical eye length and twice as broad as long; transversely inflated medially and with a transverse median row of long, declivent ammochaetae: the upper half pubescent and punctate like front, the lower half glabrous, polite, and with a very few scattered, rather coarse punctures; apical flange broad, polite, truncate, entire and not notched medially. Mandibles large, decussate, the apex acute; inner margin with two subapical teeth; lower margin subemarginate medially.

Thorax subfulgid; with a fine vestiture of appressed puberulent hair which is silvery on pleura and propodeum and aeneous dorsally. Mesonotum with coarse, scattered punctures; mesonotal laminae obliquely truncate and obliquely concave posteriorly; scutellum large, flat, with scattered, coarse punctures, the anterior margin foveolate; postscutellum transversely tumid, with a few scattered, moderately coarse punctures. Mesopleura with scattered, coarse punctures throughout except above episternauli; episternal suture, episternauli, omauli, and sternauli distinct and well developed for entire length. Metapleura impunctate, separated from propodeum by a consute suture. Propodeum with dorsal trigonal enclosure distinct, defined by a foveolate groove, bisected by a narrow, submarginate, linear furrow, the anterior half with radiating grooves separated by carinules; posterior face with separated, coarse punctures; lateral faces impunctate anteriorly to sparsely, coarsely punctate posteriorly.

Legs short, stout. Fore tarsi somewhat flattened, with a pecten of elongate, flattened, flexible bristles. Middle and hind tibiae with a few short, stout spines on outer faces. Middle and hind tarsi with verticellate whorls of stout spines at apices, and metatarsi also with a few stout spines above and laterally; hind tarsi slightly inflated. Longer calcar of hind tibiae one-half length of hind metatarsi.

Abdomen subfulgid; elongate-fusiform; with a moderate vestiture of fine, appressed, silvery puberulent hair. Tergites and sternites with a moderately coarse, separated series of punctures superposed on a very fine, setigerous acupuncturation. Pygidial area subequilaterally trigonal, the disc longitudinally, coarsely rugulose.

This distinctive species of southern Arizona's Sonoran Desert is known at present from only the unique female described above.

Arigorytes clavatus (Baker)

Hoplisoides clavatus Baker, Invertebrata Pacifica, I, p. 165, (Feb. 28, 1908) [♂; Nevada]—Maidl & Klima, Hymen. Catal., VIII, (1), p. 89, (1939).

Type. ♂; Ormsby County, Nevada. (C. F. Baker) [Pomona College?]

Although I have seen neither the type nor any material of this species, I am reasonably confident that Baker's *Hoplisoides clavatus* is referable to the genus *Arigorytes*. Some of the features given by Baker in his original description agree with characteristics of *insolitus*, others with those of *smohalla*. When the type of *clavatus* is located and examined, it may prove to be a discrete species.

THE COCKROACHES OF THE PROVINCE OF QUEBEC*

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For a long time, the order Orthoptera was a loosely interpreted group which has now been restricted to more homogeneous forms. The well known cockroaches which formed the family Blattidae are now considered as a separate order under the name of Blattaria.

The cockroaches are so well known that there is no need for a detailed description of their morphology. They are easily separated from the other insects by their soft bodies, by their oval and flattened form; the antennae are often longer than the body and are composed of many short segments; the head when at rest, is bent under and almost concealed by the pronotum, so that the mouth projects back to the base of the front legs.

These insects are very ancient. In fact, they are among the oldest and numerous species have been found from rocks principally from the Carboniferous formations.

The species of cockroaches are exceedingly abundant in tropical and subtropical regions of the globe where they reach their greatest development in the moist jungles. Some of these species, however, have spread into temperate zones through commerce principally and have become serious pests in homes.

There are at present in the Blattaria about 2250 species distributed as follows**: Neotropical region, 660 species; Ethiopian region, 610 species; Indo-Malayan region, 500 species; Australian region, 250 species; Palaearctic region, 160 species, Nearctic region, 70 species.

There is in the Province of Quebec one well known native species, *Parcoblatta pennsylvanica* (Deg.). It is found under loose bark of trees, stones, and fallen leaves. At least five other species of roaches introduced from warmer countries are found here as pests in houses and commercial establishments. They are: *Blatella germanica* (L.), the German cockroach; *Supella supellectilium* (Serv.), the brown-banded roach; *Blatta orientalis* L., the oriental roach; *Periplaneta americana* (L.), the American cockroach; *Periplaneta australasiae* (F.), the Australian roach.

Prof. E. R. Bellemare informs me that *Supella supellectilium*, the brown-banded roach, was found only once in Canada, and this was in Montreal.

A key to the species of Cockroaches (adults)
found in the Province of Quebec.

1. Size comparatively small, 11 to 13 mm. 2
   Size much larger, 16 to 40 mm. 3
2. Color light brown or yellowish; pronotum with two longitudinal brown or blackish stripes; both sexes fully winged ..... *Blatella germanica* (L.).
   Color distinctly paler; disc of pronotum brown, side margin pale yellow; wing covers variable, usually with two brown or blackish blotches on each; males fully winged, females with shorter wings ..... *Supella supellectilium* (Serv.).
3. Pronotum entirely black; wing covers of males deep brown, not reaching end of abdomen; females with vestigial wings. Length, 16 to 25 mm. ..... *Blatta orientalis* L.
   Pronotum with a large median brown or black blotch often divided in the middle by a narrow pale line 4
4. Wing covers uniformly brown, the side margins not paler; both sexes fully winged; large species, 27 to 40 mm. ..... *Periplaneta americana* (L.).
   Wing covers paler at the sides 5

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**Essig, E. O. 1942, College of Entomology.

5. Wing covers brown, sides yellow on basal third only; both sexes fully winged; length, 23 to 29 mm. ..... *Periplaneta australasiae* (F.).
Wing covers yellowish gray, pale along the sides; males fully winged, females with wings covering two-thirds or more of abdomen; length, 16 to 28 mm. ..... *Parcoblatta pennsylvanica* (Deg.).

THE PROVENTRICULUS OF A GROUND BEETLE, *CHLAENIUS* SP. (COLEOPTERA, CARABIDAE) *

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ABSTRACT

The structure of the proventriculus of a ground beetle of the genus *Chlaenius* is described. It is similar to the proventriculi of ground bettles studied by other authors, in that its sclerotized intima is organized in the form of four longitudinal folds alternating with four longitudinal ridges.

INTRODUCTION

Several authors have studied the digestive tracts of beetles of the family Carabidae and have noted the details of the structure of the proventriculus. Bordas (2) described briefly the proventriculus of a number of species in the genera *Carabus, Calosoma* and *Procrustes*. Schlüter (4) figured the proventriculus of a species of *Carabus* in which the sclerotized intima was organized in the form of eight folds traversing the length of the organ. In *Sphaeroderus nitidicollis* Chev., Schaefer (3) likewise found eight folds in the proventriculus. A similar arrangement was found by Bess (1) in the proventriculus of *Calosoma sycophanta* L. and by Whittington (5) in *Harpalus pennsylvanicus* Dej.

MATERIALS

Beetles of the genus *Chlaenius* were collected from beneath rocks and pebbles close to the water's edge along the Ottawa River, at Ottawa, Ont., Sept. 2, 1939. They were identified by Mr. W. J. Brown, Division of Entomology, Ottawa.

The digestive tract was removed from each beetle and was pinned to a layer of wax in a watch glass and was covered with water. The proventriculus was cut longitudinally with fine scissors. A section of the digestive tract including the proventriculus was then removed and placed in a strong solution of potassium hydroxide. After the muscles and otner soft tissues had been dissolved the sclerotized lining of the proventriculus was passed through several changes of water, alcohols and xylol and mounted in Canada balsam.

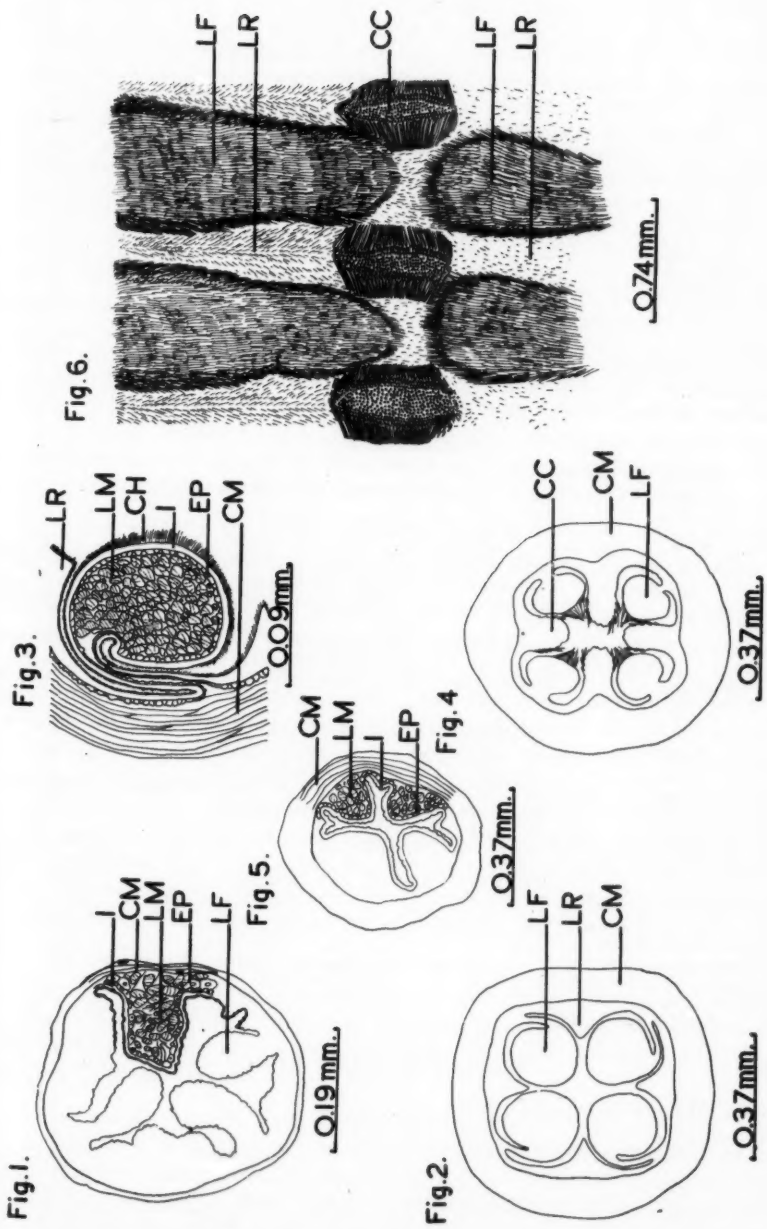
Serial transverse sections (10u) were made and stained with haemotoxylin and eosin.

DESCRIPTION

The proventriculus is spindle-shaped and 3 mm. long. The sclerotized intima (fig. 1, 3, 5 – *I*) of the organ is organized into four longitudinal folds (fig. 1, 2, 4, 6 – *LF*) alternating with four longitudinal ridges (fig. 2, 3, 6 – *LR*). The folds and ridges are beset with a thick coat of fine hairs (fig. 3 – *CH*). In the anterior end of the proventriculus the longitudinal folds are irregular in shape (fig. 1 – *LF*), while farther posteriorly they are rounded, and much constricted at their union with the wall of the proventriculus (fig. 2, 3, 4 – *LF*). In the anterior and posterior portions of the proventriculus the longitudinal ridges are less prominent than the longitudinal folds (fig. 2, 3, 6 –

*Part of a thesis submitted in accordance with the regulations for the degree of Master of Arts of the University of Western Ontario

PLATE VII



THE PROVENTRICULUS OF A GROUND BEETLE. CHLAENIUS SP.

LR). At points about two-thirds of the distance from the anterior end of the proventriculus the longitudinal folds are reduced in size and the longitudinal ridges are replaced by four cushions of closely packed sclerotized spines which project into the lumen (fig. 4, 6 — *CC*). Posterior to these cushions the longitudinal folds are again prominent and the longitudinal ridges reappear. In the region of the oesophageal valve (fig. 5) the lumen is blocked by the folds, and the ridges are small or absent.

Beneath the sclerotized intima is the epidermis (fig. 1, 3, 5, — *EP*) consisting of a single layer of roughly cubical cells. Next to the epidermis are strands of longitudinal muscle (fig. 1, 3, 5 — *LM*). They are most abundant in the cavities of the longitudinal folds (fig. 3). The outer layer of the proventriculus is composed of circular muscle (fig. 1 — 5 — *CM*). It is two or three strands thick in the anterior region of the proventriculus (fig. 1) and shows its greatest development midway along the length of the organ (fig. 3) and beneath the four cushions (fig. 4).

The foregoing description indicates that the proventriculus of *Chlaenius* is similar in structure to those of ground beetles described by other authors. The arrangement of four prominent longitudinal folds alternating with four longitudinal ridges is common to all species studied by Bess (1), Schaefer (3), Schlüter (4) and Whittington (5).

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EXPLANATION OF PLATE VII

Fig. 1. Transverse section of proventriculus at its union with the crop.
Fig. 2. Transverse section of anterior region of proventriculus.
Fig. 3. Transverse section of longitudinal fold in anterior region of proventriculus.
Fig. 4. Transverse section of middle region of proventriculus.
Fig. 5. Transverse section of oesophageal valve.
Fig. 6. Part of sclerotized intima of proventriculus.

EXPLANATION OF LETTERING

CC — cushion of spines.
CH — coating of hairs.
CM — circular muscle
EP — epidermal layer
I — intima of proventriculus
LF — longitudinal fold
LM — longitudinal muscle

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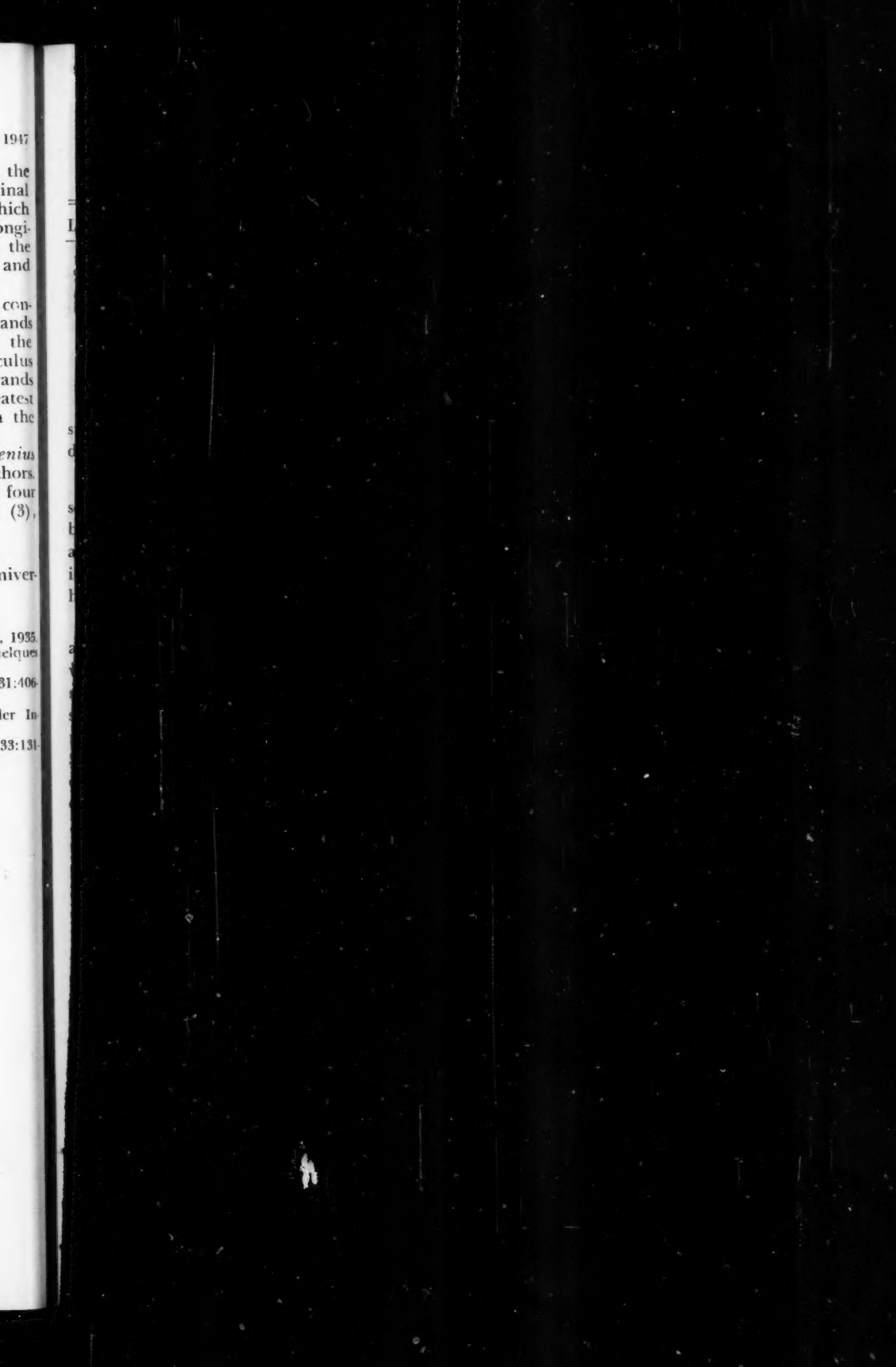
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